HydroAnalysis

TECHNICAL MEMORANDUM

To: Sean Sheldrake, Environmental Protection Agency

From: Bruce Jacobs and Ken Hickey, HydroAnalysis

Subject: **Review of Gasco Sediments Distributed Temperature Sensing Report, *January 6, 2016***

Date: January 22, 2016

This review has been prepared on behalf of the Five Tribes[1]. A report entitled *Distributed Temperature Sensing for the Detection of Groundwater Seepage, NW Natural Gasco Sediments Cleanup Action* was prepared by Anchor QEA, LLC and SelkerMetrics, LLC on behalf of NW Natural. The report describes a test of the distributed temperature sensing (DTS) technology in a "pilot installation" to identify groundwater seepage and recharge areas beneath the Willamette River. The test was carried out during operation and temporary suspension of the upland hydraulic control and containment (HC&C) system. The study area was described as a "focused-investigation area within the Site Interim Project Area."

The study featured burial of a fiber optic cable in river sediments at a depth of about 2 inches, in a zigzag pattern along a shoreline distance of 300 feet. Temperature was measured along the length of the cable in shallow sediment using the DTS technology. Identification of seepage areas was based on interpretation of the difference between the temperature measured by the cable in shallow sediment and river water temperature. In areas of groundwater discharge into the river, the shallow sediment temperature would be affected by the discharging groundwater temperature. In winter, the groundwater temperature would typically be warmer than the river water temperature and the differential between the shallow sediment temperature and river temperature would be positive. In summer, the groundwater temperature would typically be cooler than the river water temperature and the temperature differential would be negative. In areas with no groundwater seepage, the river water temperature and shallow sediment temperature would be approximately the same and the temperature differential would be approximately zero.

A brief description of the pilot seepage tests is provided below followed by general, specific, and editorial comments.

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[1] The Five Tribes comprises the Confederated Tribes of The Grand Ronde Community of Oregon, the Nez Perce Tribe, the Confederated Tribes of Siletz Indians, the Confederated Tribes of the Umatilla Indian Reservation, and the Confederated Tribes of the Warm Springs Reservation of Oregon.

Brief Project Description

The project was completed in three phases, spanning the period of September 24, 2014 to March 16, 2015, and is briefly described below.

Phase 1 Test – Phase 1 was conducted from September 25 to October 15, 2014 and did not result in measurement of groundwater seepage. The temperature difference between the river water temperature and the groundwater temperature was relatively small (a difference of 3 to 7 °F) during this period. For example, on October 6, the river temperature was 62 °F and the groundwater temperature was 59 °F. Results from this phase of the test are not shown in the report, but the report states that there were "no clear indications of groundwater seepage" during the Phase 1 investigation. This finding is attributed to the "small temperature differential between the river and groundwater temperatures and rapid cooling of the river."

Phase 2 Test - Phase 2 was conducted from January 29 to February 6, 2015 and did not result in measurement of groundwater seepage. The temperature difference between groundwater and surface water during the Phase 2 test was 10 ° to 12 °F. For example, on February 1, the river temperature was 47 °F and the groundwater temperature was 58 °F. The report states that there could be no "definitive identification of groundwater seepage or recharge" based on an assessment of the data collected during Phase 2.

Phase 3 Test - Phase 3 was conducted from March 1 to March 16, 2015. During that period the temperature difference between groundwater and river water was 6 to 11 °F. For example, on March 11, the river temperature was 49 °F and the groundwater temperature was 58.5 °F. A temperature differential between river water and shallow sediment was measured along the length of the fiber optic cable and was relatively small, ranging from approximately -0.25 °F to +0.25 °F on March 9 and March 11, 2015.

These Phase 3 results are shown in Figures 2 and 3 of the report. In each of these figures, the temperature differential between river water and shallow sediment are shown as color-coded representations with the warmer colors representing positive differentials of the shallow sediment relative to the surface water. The report states that 6 Areas of Seepage (AOSs) were identified but the criteria for AOS identification are not provided. The positive temperature differentials in Figures 2 and 3 appear to have been interpreted as areas of seepage (from the warmer ground outward into the colder river).

General Comments

1. The DTS pilot project appears to have been appropriately designed and conducted.
2. The authors accurately acknowledge that "no definitive identification of groundwater seepage or recharge could be made from assessment of" Phase 1 and Phase 2 data.
3. Phase 3 results are described as identifying 6 AOSs, but the data do not appear to support this assertion. Data that are provided show temperature differences on the order of 0.25°F between river water and shallow sediment (e.g., Figures 2 and 3). During this period, the temperature difference between river and groundwater was much larger (approximately 10° F). Differences of

roughly 0.25° F represent 3% of the river to groundwater difference. Temperature differences of this size and proportion would typically be considered insignificant and likely due to natural variability.

4. Minimal temperature data are provided in the report. It is possible that sufficient data were collected to demonstrate that seepage was occurring during the test, but these data are not presented in the report. The authors should either provide sufficient data and rationale to support the assertion that shallow sediment temperature data have identified groundwater seepage areas or withdraw the assertion.

5. Based on the data and information presented in the report, it does not appear that the pilot test has demonstrated the value of the DTS technology for identification of seepage areas at locations along the Willamette River.

Specific Comments

1. The persistence of temperature differentials over time at the AOS's has not been sufficiently documented within the report. Representative time histories of temperature differentials should be plotted for each of the AOS and for several other non-AOS areas so that the reader can understand the persistence of the temperature differentials and how they correlate with changes in river water temperature and changing system operations.

2. The most prominent feature with a consistently elevated positive temperature differential appears to be the near-shore point at the base of the driveway and to the west of the dock near the center of Figures 2 and 3. As noted in the text, the area does not show any response to pumping at the HC&C system. This area is not described within the text or on any of the figures as an AOS, although the persistent positive temperature differential might lead to a different interpretation (only two dates are shown). The detection of an area with a persistently high temperature differential warrants additional examination beyond the reference in the text to it as an "area of interest".

3. The Phase 3 data were reported to be consistent with "groundwater gradient reversal and the resulting infiltration of cold river water into the surface sediments." The report also concludes that "Groundwater seepage was dramatically slowed or reversed in the six AOSs following re-initiation of HC&C system pumping during Phase 3. Figure 3 shows the temperature differentials after the HC&C system had been restarted. Only AOS 4 in Figure 3 has a reported non-positive temperature differential that would indicate the cessation of groundwater discharge. The other five identified AOSs have positive temperature differentials between +0.051° and +0.1° F. This might be interpreted as being consistent with somewhat diminished positive groundwater seepage values persisting during the operation of the HC&C, but not a gradient reversal in which river water is recharging groundwater. Also, the differences in temperature differentials before and after pumping was resumed are subtle and do not support the conclusion that groundwater seepage had been "dramatically slowed or reversed." Absent either analytical or numerical models of the temperature field that relate temperature differentials to particular seepage rates and given the relatively small temperature differentials, the principal findings of the report are unsubstantiated.

4. Negative temperature differentials on the order of -0.25° F are apparent from inspection of Figures 2 and 3, but are not noted in the text. These negative temperature differentials are of the same approximate magnitude as the positive temperature differentials noted in the identified AOSs. These differentials and the physical sequence of events that lead to their presence should be described.

Editorial Comments

1. Figure 1 shows the six Areas of Seepage (AOS) that were identified during the Phase 3 test. The first reference to Figure 1 is on page 6, but the first reference to Areas of Seepage does not occur until page 10. This was confusing on the first read-through of the document. Removal of the AOS areas from Figure 1 would help to clarify this misunderstanding.

2. The explanation for the exposed portions of the fiber optic cable saying that they "could not be buried by the diver due to the coarse-grained or compacted nature of the surface sediment" describes two very different conditions. If the material is coarse-grained, then it likely represents an unmeasured seepage area. Compacted soils, on the other hand, would not be likely to be seepage areas. Please add some additional text to explain how much of the area where the tubing could not be buried consisted of coarse-grained material as opposed to compacted soils.

3. Understanding of Figure 5 is critical to interpretation of the test results for Phases 2 and 3. The overlap of the shaded areas denoting the Phase 2 and 3 tests and the period when the HC&C System is either on or off makes it difficult to interpret the figure. We suggest that the authors adopt a simpler graphic layout that better explains the sequence of events. Perhaps a simple time line above or beneath the chart would suffice.

4. The legend in Figures 2 and 3 describes the color-codes as representing the temperature differential between surface water and shallow sediments. Our first interpretation of this was that the value in the legend represented the difference between the surface water temperature and the temperature of the shallow sediment. Based on the text, we understand the positive temperature differentials to represent areas of seepage where the sediment temperature is greater than the river water temperature. Please clarify the meaning of "temperature differential" so that it is understandable on inspection of the figures.

5. Figures 2 and 3 are color-coded maps of the temperature differential along the fiber optic cable on March 9 and 11. Neither the text, nor the figures indicate whether these are average values over a 24-hour period or instantaneous values at a particular moment. If they are instantaneous values, then this should be noted within the text and on the figures along with the measurement time.

6. The blue shades used in the legend in Figures 2 and 3 are too close in color to identify the value of the negative temperature differentials along the length of the fiber optic cable on either figure. We suggest that the figure be amended to show contour intervals as lines with enough labeling to allow for simple interpretation of the temperature at any point along the length of the fiber optic cable.

7. The Figure 3 legend's first entry, "<-0.025", is likely a typo and is inconsistent with the remainder of the legend entries.

8. The report conclusions note the detection of AOSs is consistent with the results of data collected at offshore seepage meters and groundwater elevation measurements. Presentation of these other data sets within the report would aid the reader in understanding the veracity of this finding.

9. In a discussion of results (page 12) presented in Figure 6, the report refers to temperature changes in portions of cable "buried in coarse sediment." There are no references to temperature in portions of cable buried in coarse sediment in Figure 6. The report text or Figure 6 should be modified to restore the consistency between the text and the figure.

10. A reasonable portion of the temperature data from all three project phases should be included as an appendix to the report in order to fully document the test.